CALIBRATION CONTINUED FROM PAGE 2

entirely to the troposphere. Simultaneous observations with WVRs positioned near each antenna (separation ≤50 m) and pointing in the same direction as the radio sources were used to estimate the wet troposphere delays at the two sites. The site-differenced microwave delay residuals measured by VLBI could then be compared to the site-differenced wet delays determined directly by the WVRs.

We did comparisons in two ways. The first was an interscan comparison. We obtained 30 scans, typically 2 to 3 min each and covering a wide range of directions on the sky, for which the DSN and WVR antennas were copointed to better than 1 deg at both ends of the baseline. The VLBI and WVR site-differenced line-of-sight delays are plotted as a function of universal time (UT) in Figure 1. The delays have been mapped to zenith to remove variations due to elevation-angle differences between scans. A very strong correlation between the VLBI and WVR data is evident over the full 14 h of the observations. An important metric for assessing the quality of WVR calibration is the ability of the calibration to reduce the root mean square (rms) of the postfit VLBI delay residuals. The rms was 43.8 ps without WVR calibration and 16.9 ps after applying the WVR calibration as a correction to the data before the parameter estimation step of data analysis. WVR calibration yielded a factor of nearly 3 reduction in the postfit residuals. Since these rms values were calculated after the subtraction of a mean tropospheric zenith delay, they represent the effects of tropospheric fluctuations.

Our second comparison was an intrascan test. We had two long scans (30 to 40 min) with valid VLBI and WVR data. The first long scan was in the early a.m., when the troposphere was quiet. WVR calibration did not reduce the level of fluctuations within this scan. The second long scan was in the early p.m., when the troposphere was very active (large-scale convection). The VLBI and WVR site-differenced delays for this scan are plotted as a function of time since scan start (in seconds), in Figure 2. A point is plotted every 6 s for both the WVR and VLBI data. Once again, a very strong correlation between the VLBI and WVR data is evident, confirming that the VLBI line-of-sight (LOS) delay residual is troposphere dominated and demonstrating that WVRs can measure variations in tropospheric delay on short time scales. For this scan, WVR calibration reduced the level of fluctuations by a factor of 2 on time scales longer than about 200 s. On shorter time scales, the thermal noise in the WVRs and the effects of a 50-m separation between WVR and DSN antennas precluded useful calibration.

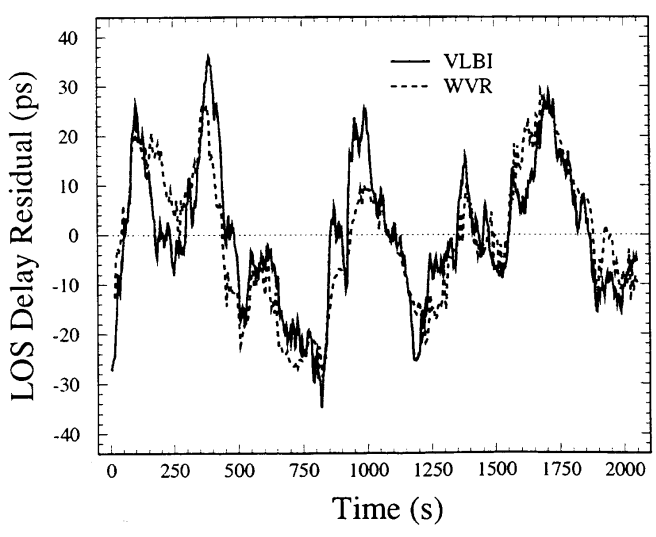

FIGURE 2. SITE-DIFFERENCED DELAYS VS. TIME SINCE SCAN START.

Conclusion

The results from this test are encouraging, and are substantially better than any previous results using WVRs. Our level of calibration accuracy is generally consistent with our estimates of the accuracy of current WVRs and the effects introduced by the wide WVR beams (6 to 9 deg), 50-m WVR–DSN offsets, and the fact that the WVRs do not track the sidereal motion of the radio sources during data taking. While the existing generation of WVRs cannot meet the Cassini Radio Science requirements, their performance has given us confidence that we understand the error budget for the calibration system. An

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space applications of smaller–cheaper–better spacecraft using optical communications systems.

Vincent Pollmeier describes a new astrometric camera system using one of the largest CCDs currently available; this CCD provides an order of magnitude improvement over other existing instruments. This system is presently undergoing tests at TMF and will be used to accurately position solar-system bodies, including future laser-bearing spacecraft missions, relative to the highly accurate known-star positions available from the Hipparcos star catalog.

The high-performance large DSN antennas are available for limited-time radio-astronomy measurements. Tom Kuiper, Bill Langer, and "Velu" Velusamy describe an important example of the antenna's unique capability by measuring pre-protostellar structure maps, which are critical for star formation studies. These radio astronomy measurements at 22, 34, 45, and 90 (future) GHz—well above the standard DSN frequencies—stress the DSN antennas capability and feed back useful antenna performance data to the implementation teams.

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advanced WVR is presently under development. Recent test measurements on a first laboratory prototype have demonstrated thermal control and gain stability that meet or exceed the Cassini goals. A field prototype will look at the sky soon. In the next fiscal year we plan to perform a follow-up VLBI/WVR experiment with a prototype system that will closely resemble the Cassini operational system, including illumination of the radiometer by a 1-m, clear-aperture antenna. This aperture will result in a much narrower WVR beam (1 to 2 deg), thereby reducing errors due to WVR–DSN antenna beam mismatch and enabling observations down to much lower elevation angles. Improvements in sensitivity and gain stability will lower the instrument noise floor. The follow-up VLBI/WVR experiment should, therefore, demonstrate even more impressive troposphere calibration capability, and it is certain to deepen our understanding of the error budget. The advanced WVR development will culminate in a convincing demonstration that the operational system will meet the Cassini goals.

GOLD CONTINUED FROM PAGE 9

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